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6. AUTHOR(S)
Jason D. Schwartz, CPT(P), MS

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Brooke Army Medical Center
3851 Roger Brooke Drive
Fort Sam Houston, TX 78234

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Brooke Army Medical Center (BAMC) is analyzing methods to optimize the operating room (OR). One goal of BAMC's OR is to capture supply costs associated with different procedures as well as to assign the costs to patients. Another goal is to provide real time access to supplies for patient care for a variety of elective and non-elective surgeries in a tertiary care medical center with a level I trauma mission. A cost effective analysis was conducted to compare Pyxis, a secure cabinet that uses touch-to-take technology, to bar coding technology. The study was conducted in two phases. The first phase used the Army decision making tool, DECMAT, to decide which system best accomplished the goals of the study. Pyxis with a value of 3.751 was chosen over bar coding, 1.000E9. The second phase of the study measured how accurately the selected system, Pyxis, calculated the costs of the supplies used for designated procedures versus using physician preference cards, prime vendor pricing lists, credit card purchases, and contracts to manually calculate the costs of supplies. The statistical software package, Statistical Package for Social Sciences (SPSS) 12.0.1, was utilized to determine the variance for the dependent variable, current procedural terminology codes (CPT) codes, and the two independent variables, manual and Pyxis calculation of costs. Descriptive statistics were utilized to determine the mean and standard deviation for the manual calculations as $2,726.61 and $2,573.84; and $2,799.33 and $2,646.08 for Pyxis. An Independent T-test and ANOVA table was used to determine the statistical significance of the variation. The F-test value, .015 and .003, for both tests illustrated little scientific significance between the two independent variables.

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A Cost-benefit between Pyxis and Bar Coding for the Brooke Army

Medical Center Operating Room

CPT Jay Schwartz

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Abstract

Brooke Army Medical Center (BAMC) is analyzing methods to optimize the operating room (OR). One goal of BAMC's OR is to capture supply costs associated with different procedures as well as to assign the costs to patients. Another goal is to provide real time access to supplies for patient care for a variety of elective and non-elective surgeries in a tertiary care medical center with a level I trauma mission. A cost effective analysis was conducted to compare Pyxis, a secure cabinet that uses touch-to-take technology, to bar coding technology. The study was conducted in two phases. The first phase used the Army decision making tool, DECMAT, to decide which system best accomplished the goals of the study. Pyxis with a value of 3.751 was chosen over bar coding, 1.000E9. The second phase of the study measured how accurately the selected system, Pyxis, calculated the costs of the supplies used for designated procedures versus using physician preference cards, prime vendor pricing lists, credit card purchases, and contracts to manually calculate the costs of supplies. The statistical software package, Statistical Package for Social Sciences (SPSS) 12.0.1, was utilized to determine the variance for the dependent variable, current procedural terminology codes (CPT) codes, and the two independent variables, manual and Pyxis calculation of costs. Descriptive statistics were utilized to determine the mean and standard deviation for the manual calculations as \$2,726.61 and \$2,573.84; and \$2,799.33 and \$2,646.08 for Pyxis. An Independent T-test and ANOVA table was used to determine the statistical significance of the variation. The F-test value, .015 and .003, for both tests illustrated little scientific significance between the two independent variables.

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## Introduction

*Conditions which prompted the study*

A key to delivering quality outcomes is the assurance of timely, accurate delivery of supplies and medications. The Brooke Army Medical Center (BAMC) operating room (OR) staff uses a system called Pyxis. Pyxis is a secure cabinet that uses touch-to-take technology designed to provide rapid access to patient care inventory, while eliminating unnecessary search and billing steps. Additionally, Pyxis has the capability to electronically capture supply usage rates, inventory levels, and transmit replenishment information to the logistics division of the hospital (Cardinal.com, 2004).

An alternative system used by hospitals is bar coding. Bar coding places labels on supplies for identification purposes and is similar to systems used in supermarkets. The codes are scanned and allow hospitals the ability to collect and analyze information as well as eliminate redundancies, inaccuracies, and delays in administrative processes.

One goal of the BAMC operating room staff is to capture supply costs associated with different procedures as well as to properly assign these costs to patients. Another goal is to provide real time access to supplies for patient care for a variety of elective and non-elective surgeries in a tertiary care medical center with a level I trauma mission. If both goals are achieved, the information gathered is invaluable to identify cost savings for budgeting and increasing efficiencies for operating room staff and patient scheduling. Through initial interviews with the Chief, Surgery; Chief, Preoperative Services; and the OR Head Nurse, they feel that Pyxis is a good system, but question whether it is the best system for BAMC. This study conducts cost effectiveness analysis between Pyxis and bar coding OR cost accounting systems.

*Statement of the Problem/Question*

The analysis is to determine which system, Pyxis or bar coding, is best suited for the BAMC ORs to capture supply costs associated with different procedures, to assign the supply costs to patients, and to streamline the logistical process. The BAMC Commander is seeking a recommendation as to which system, Pyxis or bar coding, is best suited for the BAMC OR. Additionally, for the system that is chosen, how accurately does the electronic system calculate the costs of the supplies used for the procedure versus using prime vendor pricing lists to manually calculate the costs of supplies from physician preference cards, credit cards purchases, and contracts.

*Literature Review*

Prior to the nineteenth century, surgical procedures were performed in a patient's home or a physician's office. The personnel (anesthetist, surgeon, and assistant) would go to the patient's home, draw the blinds, and set up an operating area. Many developments in health care in the nineteenth century dramatically changed how operations were conducted. Perhaps the most significant advancement was the development of the understanding of asepsis from the work of researchers such as Pasteur, Lister Koch, and Semmelweis (Brown, 1994). Their discoveries in aseptic technique allowed longer and more complicated surgical procedures to be performed, which required the development of more modern and safer anesthetic techniques. Aiding in the diagnosis and treatment of surgical patients were advances in radiography, blood storage techniques, and clinical laboratories (Malangoni, 1997). By the end of the nineteenth century and the beginning of the twentieth century, it appeared safer and more convenient to perform surgeries in facilities specifically designed for the care of patients

by surgical practitioners, namely the acute care hospitals. Thus, hospital facilities began to frequently include specialized procedure areas or operating rooms (Harris & Zitzmann, 1998).

As the twentieth century progressed, ORs began to evolve into specialty-specific areas and hospitals increasingly became filled with surgical patients. This evolution was complicated by the need for more specialized and expensive equipment, OR surgical nurses with specialized technical skills, and even anesthetists with specialized skills (Brown, 1994). Additionally, rising costs and increased reliance on technology played a more important role in the delivery of health care. Before the inception of managed care and the prospective payment system, hospitals were reimbursed for expenses incurred in the OR on a retrospective basis. Controlling costs was not as important as maintaining reputation or hospital census. The ORs were run for the convenience of the surgeons who would bring patients to the hospital. Little attention was paid, for instance, to costly gaps in the schedule because it would be inconvenient to an influential surgeon (Malangoni, 1997). However, as reimbursement shifted from a retrospective basis (reimbursed for allowable costs as they happen and receive a final settlement when the care is complete) to prospective (the payer knows how much they will reimburse for each category of care provided), capitation and diagnosis-related-group (DRG) based systems, inefficiencies became less tolerable, a profit motive was established, and gaps were recognized as expensive and non-reimbursable time (Kongstvedt, 2000). The incentive to please the influential surgeon was removed by the development of health maintenance organization (HMO) – hospital relationships in which patients are directed to a specific

hospital not by the individual provider. This paradigm shift in business process seeks to improve efficiency through decreased per-case costs (Harris & Zitzmann, 1998).

The development of managed care further stressed the importance of controlling costs. Managed care is "a system of health care delivery that seeks to achieve efficiencies by integrating the basic functions of health care delivery, employs mechanisms to control utilization of medical services, and determines the price at which the services are purchased, and consequently how much the providers are paid." (Shi & Singh, 2001 p. 9). Managed care terms such as cost containment, primary care manager(s), case management, gate keeping, utilization, and peer reviews are common terminology used in managed care and are playing a larger role in the delivery of health care in the United States. In response to this change in business practice, hospitals have begun establishing minor surgery (outpatient) ORs outside the traditional hospital locations. Outpatient OR suites within hospitals are commonly segregated from inpatient suites and, in fact, freestanding surgery centers have increased as well as surgery suites within physicians' offices.

This change of business practice to decentralize minor surgery away from hospitals has changed the approach of the OR manager in some organizations from retrospective to prospective. OR managers are defined as "Persons appointed to positions of authority who enable others to do their work effectively, who have responsibility for resource utilization, and who are accountable for work results. OR managers range from personnel who run the day to day operations, senior nurse or anesthesiologist, to policy makers, chief, surgery; chief, perioperative services, or committees" (Harris & Zitzmann, 1998, p. 55). As a result of the OR business rules changes, the complexity of operating

rooms have increased, therefore, OR managers must provide oversight of essential OR business functions, such as, staffing, material management, and cost accounting.

Cost accounting is an essential tool for managing a complex OR suite. Cost accounting is defined as, "A method of accounting which provides for assembling and recording all elements of cost incurred to accomplish a purpose, to carry on an activity or operation, or to complete a unit of work or a specific job." (Cleverly & Cameron, 2003). Information (supply, labor, and equipment costs) provided by well-designed accounting systems assist organizations to make fundamental business decisions. The accounting system should be able to distinguish domains in which the OR suite is performing well from domains that need improvement. Information from accounting systems offer early warning of adverse trends (increase in supply or labor costs) and predict the probability of success of new initiatives (Tan, 1998).

Despite the critical role routinely played by the cost accounting system, hospitals are often not properly prepared in this area. "Hospitals are notorious for their sparse investment in information-processing equipment and personnel. In addition, medically trained personnel frequently are poorly informed about the techniques of managerial accounting and tend to underestimate its usefulness." (Gabiel et al, 1999, p. 113).

In the 1960s, most hospitals were nonprofit businesses, charging patients or their insurers for the cost of each health care service delivered plus a small margin. For most patients, the cost of hospital care was covered by indemnity insurance, which reimbursed the patient all or a portion (typically 80%) of out-of-pocket expenditures (Yasin, Small & Small, 2004). During this timeframe, the federal government introduced two programs, Medicare for the elderly and Medicaid for the poor, that directly paid for health care.

Similar to the private sector, these government programs covered the cost of care plus a small margin which equates to a cost-plus system (Gabel et al, 1999).

Under a cost-plus system, the price charged by hospitals was determined by the volume of care provided. Each day of hospitalization, each laboratory test ordered, and each medication dispensed created a charge that increased the eventual reimbursement. Hospital managers established a charge for each reimbursable service provided. Some charges were time based, such as the number of days in the hospital or in the ICU (Gabel et al, 1999). Typically in the OR suite, higher payments were made for longer cases so little attention was paid to the nature of the actual surgical operations performed, the supplies used, or the equipment required. Whether the charges bore a close relationship to the actual cost of providing the services did not seem relevant. As long as the total reimbursement met the total cost of running the hospital and the individual charges met the insurer's and the government's accounting standards, hospital managers, insurance companies, and government auditors seemed satisfied (Yasin, Small & Small, 2004). Consequently, over the years the relationship between costs and charges has become vague and inconsistent, with large overestimates and underestimates for individual services.

Cost-plus payment encouraged hospital managers to capture every detail of supplies used and services rendered to maximize charges and subsequent reimbursements. It also encouraged managers to concentrate on efficient billing and collection systems to maximize revenues. This system provided little incentive to reduce costs or to provide services in an efficient manner. Furthermore, it neither encouraged

accurate determination of the true cost of individual services nor placed any pressure on hospital OR managers for OR cost control (Gabiel et al, 1999).

Problems with government-funded indemnity reimbursement appeared almost immediately after the start of Medicare in 1965. The most substantial difficulty was that the unmet demand for medical care was far higher than Congress and the government planners anticipated. As a result, expenditures frequently exceeded budgetary allotments. From 1960 to 1985, health care expenditures in the United States increased from 5.2 to 10.6 percent of the gross domestic product (Santerre, Grubaugh, & Stollar, 1991 p. 1). Additionally, because patients with health insurance generally pay a small deductible and 20 percent co-payment, they are largely insulated from the total cost of health. As a result, consumers exerted little or no pressure for the government to contain health care expenditures. This phenomenon is called moral hazard. Shi and Singh in their book, *Delivery of Health in America*, define moral hazard as, "As a general rule, having health insurance leads people to consume more health care services than they would have purchased if they had to pay for such services." (Shi and Singh, 2001).

In an attempt to control health care expenditures, the federal government replaced Medicare's cost-plus system with the Diagnostic Related Group (DRG) reimbursement method in 1983. Under this system, after each patient's discharge from the hospital, the billing department assigns the patient a DRG code based on the discharge diagnosis. Payment to the hospital for each patient discharged with a given DRG is a fixed amount, regardless of the amount of resources expended (Kongstvedt, 2000).

To remain financially solvent, hospitals must determine which DRGs increase revenue and which DRGs reduce revenue. As a result, the hospital's interest shifts from

developing and maintaining systems designed to maximize charges under the cost plus system to systems designed to identify the true cost of providing health care services associated with each DRG. A hospital unable to distinguish between revenue generating DRGs and non-revenue generating DRGs runs a risk of financial disaster. Therefore, hospital managers must develop accounting systems capable of determining and tracking costs of all services provided to each patient in each DRG (Malangoni, 1997). This process has two elements. First, for each patient, the hospital must accurately track the relevant resources used throughout a hospital stay and be able to connect those resources with the patient's DRG. Second, the hospital must know the full cost of each service provided (e.g. costs of surgical operations, post operative care, meals, laboratory tests, and x-rays) (Gabiel et al, 1999).

To perform surgery in a safe, efficient, and economical manner, all necessary instruments, supplies, and equipment must be reliably brought together at the correct time and correct place. It is not a question of whether you can control inventory in the operating room, but rather a question of when. The change in business practices due to managed care and the prospective DRG reimbursement system have changed most hospital's operating rooms from a revenue center into a cost center (Harris et al, 1998). This is due to the limitation of DRG reimbursement for each of the cases performed. It is necessary to control inventories to ensure profitability of those procedures.

This task is not at an easy process. Most operating rooms require a large inventory of supplies for most organizations. The dollar value involved may be 20 to 40 percent of an entire hospital's supply inventory budget; Brooke Army Medical Center's operating room supply inventory is twenty-five percent of BAMC's overall budget for

supply and equipment (Mindingall, personal communication, November 9, 2004). Good materials management is imperative and requires good communication, collaboration, process orientation, and an effective information system (Rodriquez, 1989).

Communication lines must be established vertically and horizontally and there must be dialogue between different departments at several levels. The OR manager must communicate frequently and effectively with the staff and support personnel within several departments to accomplish this task. Mechanisms must also be established to involve clinicians in all phases of materials management programs (Bingham, 1989). This leads to greater standardization of equipment, greater physician buy in, and ensures physicians will use the equipment that is purchased.

Collaborating is also essential. It is important to recognize that increased efficiency in managing the operating room inventory requires increased materials management techniques which can be applied to reduce and control the inventory in the operating room (Brown, 1994). These techniques include: standardizing products, reducing inventory volume based on user sensitive distribution systems, contracting for prime vendors to drive prices down based on collective agreements between high user departments, bundling products, and reducing the variety of products (Rodriguez, 1989).

Orienting staff to the process of the materials management program is essential to its success in the operating room and allows for success in familiarizing the staff with new procedures (Brown, 1994). The supply systems are dynamic and require maintenance just as other systems do. Inventory management in the operating room cannot be a one time clean up. Systems and procedures must be implemented to support

change. Changes in staffing patterns and revisions of duties and roles must be planned and implemented to support new procedures (Brown, 1994).

Fewer places in health care rely on information to be delivered quickly and accurately than the OR suite. The responsibility of providing accurate patient information is enormous. Resources are used quickly, with little time to consider costs; however, they play a significant role in determining the hospital's profits or losses. The OR and perioperative areas represent a large portion of hospital expenditures. Information management systems can help determine actual OR costs which aid in determining profits or losses for the hospital (Malagoni, 1997).

Before purchasing an information management system, organizations must understand the needs of the users and the business process of the hospital (Haag, Cummings & McCubbrey, 2004). It must also define who the users will be and in what format the information will be provided. In order to provide seamless, quality care, accurate information is a necessity (Haag et al, 2004).

The information needed by health care organizations varies greatly among users and may represent past, present, and future data. Information systems provide data for problem resolution for productivity, history, conflict resolution, resource management, work redesign, and revenue. Mark Malangoni in his book, *Critical Issues in Operating Management*, portrays patient information as an encyclopedia. "Most paper-based patient information systems resemble an encyclopedia in that the information is neatly stacked by source, and not by logic implied by a disease state. The tabs represent the data sources, not the problems the patient faces. Like entries in an encyclopedia, one tab

may not be at all related to the next tab. An OR information system should provide a logical path through disease states" (Malagoni, 1997, p 95).

With an increasing emphasis on constraining the cost of health care, many OR managers are now working with surgeons to standardize instrument sets and supplies to help reduce the costs of procedures and facilitate cost comparisons among practitioners performing similar procedures. Hospitals can use the cost of supplies and personnel, coupled with patient outcomes, to measure whether the financial and clinical goals of the OR are being achieved. This information is especially important for medical treatment facility (MTF) commanders as the Department of Defense (DoD) implements the TRICARE next generation of contracts (T-NEX). Under the T-Nex contracts, the MTF commander has greater control and fiscal responsibility for the enrolled population. Under current business rules, if a patient is referred to the network, the costs are was covered under a centralized pool of supplemental care funds at the DoD level. Under the new business rules of T-Nex, the MTF is allocated a portion of money per member per month for his/her enrolled population. If a patient is referred to the network, the MTF is responsible for paying for the care out of the hospitals operating budget. This places more emphasis on the hospital management to make sound business decisions as to what is referred to the network and what can be captured in the MTF (www.tricare.osd.mil, 2004).

Ensuring reliable and timely availability of the requisite instruments, supplies, equipment, and personnel in every OR to facilitate the performance of surgery is one of the three major problems identified by Gabel et al (1999). Others are scheduling cases and managing personnel. The logistics of supplying and staffing ORs is far more

complex than the comparable task in a manufacturing environment. Rather, the procedures vary from case to case, from surgeon to surgeon, and from day to day. Gabel et al estimate that an average OR must stock at least 10 times as many different items of inventory as a manufacturing firm that has the same dollar volume. Prices of the various items range from $.01 for gauze sponges to thousands of dollars for items such as pacemakers, artificial heart values, and orthopedic joint implants (Gabiel et al, 1999).

Additionally, an OR suite must have all supplies and instruments on hand before the start of the case. Unavailability of a single essential item in the midst of surgery may force the surgeon to perform the case less than optimally, or may even cause the surgery to be discontinued, completed at a later date, or may cause harm to the patient.

To reduce the occurrence of surgery delays or cancellations, operating room systems should be comprised of three major components: (1) computer hardware and an operating system, (2) a database containing the required information, and (3) the software needed to carry out various functions such as scheduling, cost accounting, and inventory management. The computer software and hardware are often collectively called the operating room information system (ORIS). An ORIS is usually a hybrid of financial, management, and clinical information systems (Tan, 1998). Whatever its exact configuration or origins, the ORIS should possess certain general characteristics. First, the ORIS should be linked to the database that is connected with the hospital's medical information system (MIS). This allows for a two-way communication for exchange of information between the ORIS and the database (Haag et al, 2004). For example, patient demographic data from the MIS is readily available when operations are scheduled or reports from the database are prepared. In addition, the MIS has online access to all the

information in the database. To allow this free flow of information, unique identifiers for patients and episodes of patient care are needed in each of the components systems (Gabel et al, 1999).

Second, the database should be perceived as belonging to the institution as a whole, rather than to any special interest group(Gabel et al, 1999). Specifically, the database should not be viewed as belonging to the nurses, the anesthesiologists, or the surgeons. Occasionally, perceived ownership is established early in the development of the ORIS, and substantial efforts must be expended to assure that the database is not considered to be a resource developed by one professional group or another to achieve or retain power (Tan, 1998).

Third, the ORIS and database must have credibility. When resources are being allocated or attempts made to modify behavior, those with a vested interest are likely to try to discredit the data supporting change. Data integrity is the key essential task to establishing the reliability and validity of the ORIS and database (Austin & Boxerman, 1998). Cooper and Schindler define reliability as, "the degree it supplies consistent results. Reliability has to do with the accuracy and precision of the measurement procedure. Validity is the extent to which differences found with a measuring tool reflect true differences among participants being tested. Validity refers to the extent to which a test measures what we actually wish to measure" (Cooper and Schindler, 2003, p. 231).

Fourth, as much as possible, the database should be quantitative and amendable to graphical and statistical analysis. Statistical process control is a powerful tool in health care management (Tan, 1998). Although most of the data should be quantitative, explanatory information does have a role. For example, recording delays in the OR

schedule from a standard list sometimes excludes important extenuating circumstances. For such situations, a text field in which explanatory information may be entered is helpful (Gabel et al, 1999).

Fifth, the ORIS should comprehensively meet the management information needs of the OR suite. These include: scheduling patients, cost accounting, materials management, surgeon's preference cards, and tracking cases progressing through the OR (Malangoni, 1997).

Finally, all of these functions should be integrated. For example, when an operation is scheduled, the OR inventory should be checked to ensure that the necessary equipment and supplies are or will be available. Additionally, equipment and major supply items should be earmarked during the scheduling process for use during the operation being scheduled. An order can then be generated to replace major items scheduled for use, or those items can be added to an order that is continuously generated but only periodically transmitted (Tan, 1998).

Brooke Army Medical Center uses an ORIS point of use inventory management called Pyxis 6.2. The system is a supply storage system that automates distribution, management and control of medical surgical supplies, and inventory. Through a secured supply storage cabinet and touch-to-take technology, Pyxis is designed to provide a secure, rapid access to patient care inventory, while eliminating unnecessary search and billing steps. By entering an ID and optional password at secure stations in the operating room and following menus, users can obtain supplies within seconds. At the time of access all transaction information including the name of the patient, the description and

quantity of supplies removed, and the associated procedure, service, and physician is automatically recorded for accounting, restocking, and billing (Friedman, 1994).

The advantages of the Pyxis system are that it increases the product availability (a re-order request is submitted when the "Take" button is pushed and the item is removed from the cabinet), improves safety, eliminates product searches (lights show the location of the item), and eliminates stickers and manual data entry. In addition, it assists with accuracy by providing real time reports, listing line item quantity levels, eliminating billing and inventory errors, and creating new efficiencies in the supply management process (www.pyxis.com, 2004).

However, personnel in the BAMC operating room have expressed displeasures with the Pyxis system. One problem that was expressed was the amount of time to retrieve an item from the cabinet. The OR is a fast paced environment where time is essential in providing patient care. The Pyxis system requires additional steps, though small, and adds additional time to retrieving an item. During emergencies, every second counts so any added steps increases risk to the patient. Also, if the wrong code is entered, it has a negative effect on the care of the patient and/or the supply management of the OR. Stock levels are not accurate and additional time is required to reconcile inventory levels (Leandry, personal communication, August 6, 2004).

Another problem associated with the Pyxis system is accurately assigning costs to patients for itemized billing and determining the supply costs of different procedures. Due to the lack of standardization between similar items, a majority of the supplies associated with different procedures are charges to floor stock. Floor stock is the generic code that allows items to be charged quickly, but is not charged to specific patients.

Therefore, costs cannot be assigned to a specific item or used to charge the patient under itemized billing (McAfee, personal communication, August 6, 2004).

Finally, since Pyxis is an automated system, training is required to ensure the system is being used effectively and efficiently. Automation is designed to streamline and improve processes, but requires training and a basic understanding of automation systems. The BAMC OR staff expressed that the Pyxis is being underutilized due to the lack of understating of the capabilities of the Pyxis system. This inefficiency has created a sense of distrust of the system and increasing frustration levels among the staff (McAfee, personal communication, August 6, 2004).

These issues have raised questions among the BAMC leadership about the viability of the Pyxis system. This lack of confidence has resulted in the consideration of alternative methods for supplying the operating room. In an effort to reach BAMC's goal of determining supply costs of various procedures and the ability to generate itemized bills for patients, bar coding has been used an alternate system to Pyxis. Bar coding is a relatively low-risk technology in terms of costs and implementation and does not require intensive training. According to the Chief Operating Officer Terance Kinninger of Bridge Medical, Solana Beach, CA, "Bar coding systems are sophisticated in what they do, but they are easy to use as proven through their widespread use in other industries. In my experience, advanced computerized point of care systems take three to five years to put in place whereas a bar coding system can be implemented within six months." (May, 2003, p. 12).

From an administrative perspective, bar coding provides a myriad of efficiencies. Bar coding provides the opportunity to collect and analyze information as well as

eliminate redundancies, inaccuracies, and delays in administrative processes. For example, bar coding technology allows providers to match a bar code associated with a patient to the bar code associated with a medication to validate that the right patient is receiving the right procedures and/or medications. Bar coding allows a significant amount of labor costs to be pulled out of the system and reduces the paper documentation. It also allows healthcare organizations to reduce their inventory carrying costs. This reduction, in theory, leads to better cost accounting and resource management analysis that allows organizations to achieve higher charge capture rates and to receive higher reimbursement rates (May, 2003).

Bar coding technology can link patient data with outcomes information and financial data. It provides a tool for physicians and nurses to gain access to clinical information anytime and anywhere. This ability can result in better clinical outcomes and may result in a reduction of error-related liability, thus, which may decrease malpractice insurance premiums (May, 2003).

*Purpose Statement*

The purpose of this study was to identify data to conduct a cost effective analysis of the Pyxis touch and take system versus bar coding in the Brooke Army Medical Center Operating Room. The information will be used to determine which system is best to capture supply costs associated with different surgical procedures performed in the operating room as well as to properly assign these costs to patients.

## Method and Procedures

Examining the economic consequences of medical practice protects the welfare of patients. The cost of medical interventions must be balanced against patient outcomes

produced and the amount of money that the health care organization is willing to spend (Sperry, 1997).

The economic approach to resource allocation is based on two (2) key concepts. First is the scarcity and limited useful life of resources and second, is realizing that since resources are scarce it forces decision-makers to make choices about how the available resources should be used. When resources are allocated to one program others do not get the needed resources. An economic analysis attempts to ensure that the benefits of a particular choice exceed the costs, as well as the benefits of other alternatives. The latter considers the concept of opportunity costs. An opportunity costs is the value the resource could have produced if it were directed toward its next best available alternative (Heyland, Gafni, Kernerman, Keenan, & Chalfin, 1999).

In health care, one goal is to maximize health benefits, the results (effects) on health of any type of process. This often leads to ensuring that the value of what we choose to do with the available resources must be at least as great as the opportunity cost. These considerations are used to ensure that the best outcomes are achieved for a given level of expenditure. This concept is called economic efficiency (Heyland, et al, 1999).

Economic evaluations systematically consider all possible costs and benefits of a potential decision. Even though an economic analysis is not the sole basis for a decision, it is a useful tool that can be used by health care providers and administrators when making decisions on the use of scarce resources. An economic evaluation offers information that can be used to maximize health benefits of the community given the available level of resources (Henderson,2002).

A cost effectiveness analysis incorporates both cost and outcome into the analysis. Outcomes are measured using a common scale, such as increased procedures performed or increased efficiency of the staff. Cost effectiveness analysis is appropriate when one of two standards are met: (1) when the processes being compared produce identical outcomes, and (2) when a single objective is easily measured (Henderson, 2002).

Bruce Schrimer and David Rattner provide additional information to define cost effectiveness analysis, "Cost effectiveness is that the ratio of "value" to cost is higher than for competing alternatives...Formally, cost effectiveness is one specific type of analysis among a family of analytic tools that are used to evaluate the relative merits of health and other programs." They further state, "Cost effectiveness is what economists refer to as a normative concept. It attempts to define what should be, which requires an assessment of value, which in turn, cannot be divorced from value judgments" (Schrimer & Rattner, 1998, p.12).

This study was conducted in two (2) phases. The first phase was a cost effectiveness analysis between bar coding and Pyxis. The study used variables operationally defined in Appendix A to compare bar coding and the Pyxis system in the operating room. To increase validity and reliability, the variables were approved by a Quality Assurance Committee (QAC). The committee consisted of personnel from the Operating Room, Department of Surgery, Central Materials Services (CMS), Department of Nursing, Department of Logistics, and Department of Clinical Operations. A complete list of the committee members and their duty titles are listed in Appendix B. The variables were then weighted using a scale of one to seven (7). The scoring range was from one (1), lowest importance, to seven (7), highest importance. The total score for

each variable was then divided by eighteen (18) (the number of people ranking the variables) to obtain an average weight for the variable. See Appendix C for questionnaire.

The study recognizes that this method provides a subjective assessment that reflects relative advantages or disadvantages for each variable. By assigning numerical values to the variables, it allows the study to produce a scientific comparison. In addition, weighting the variables allows the rater the ability to express which variables are more or less important than other and is a subjective assessment that creates greater dispersion in the numerical results and makes choices easier to differentiate (CGSC Tactical Decision Making Process, 1993).

The next step of the decision matrix was for the Quality Assurance Committee to use the weighted variables to decide which system is better to address the variable. For example, if the Pyxis system is selected, a two (2) is assigned and bar coding is assigned a value of one (1). An example using the labor variable (personal required to operate system), bar coding requires on the average of four (4) to five (5) people to efficiently manage the system in the OR (MSgt Thorpe, personnel communication, October 8, 2004). The Pyxis system requires one to two people to operate efficiently (COL Peralta, personal communication, September 29, 2004). Therefore, the rater would assign the weighted value of labor to the Pyxis system. This process would continue for the remaining variables and entered into the Army's decision making matrix, DECMAT, to determine which system is the best course of action.

The second phase of the study examined how well the selected system measured the costs of procedures conducted in the operating room. Eight high cost (8) current

procedural terminology codes (CPT) codes were identified by the Quality Assurance Committee. From the CPT codes identified, the costs associated with each procedure were identified through a manual process using physician preference cards, credit card purchases, contracts, and the Defense Medical Logistics Standard Support (DMLSS). DMLSS is co-sponsored by the Assistant Secretary of Defense (Health Affairs) and the Deputy Under Secretary of Defense (Logistics). It is a partnership involving the wholesale medical logistics, medical information management, medical information technology, and user communities. DMLSS' mission is to improve responsiveness of medical logistics support. The DMLSS Program accomplishes this by implementing business process innovations that increase the effectiveness of medical logistics support while reducing costs. (http://www.tricare.osd.mil/dmlss/default.cfm, 2004).

The next step in the analysis was to determine the variance between manually calculating the cost per procedure verus using the Pyxis system. In theory, both processes should be the same since they operate from the same pricing list in DMLSS, however, some procedures require the purchase and use of supplies that are not loaded into DMLSS. These supplies are purchased through government credit cards and contracts. If these items are purchased through credit card or contract, the standard operating procedure (SOP) is for the logistical specialist to enter the information retrospectively into DMLSS (LTC Riley, personal communication, October 20, 2004). Appendix C illustrates how surgical costs are captured through the manual process and the Pyxis system.

Once the costs per CPT code were captured for each process, the statistical software package, Statistical Package for the Social Sciences (SPSS) 12.0.1, was used to

conduct an analysis of the reliability, validity, and variance. SPSS is a software package used for conducting statistical analyses, manipulating data, and generating tables and graphs that summarize data. Statistical analyses range from basic descriptive statistics, such as averages and frequencies, to advanced inferential statistics, such as regression models, analysis of variance, and factor analysis. The statistical test, T-test and ANOVA, were used to determine the variance between the manual process and Pyxis process. The Independent T-test is the most commonly used method to evaluate the differences in means between two groups. The groups can be independent or dependent. The equality of variances assumption can be verified with the F test (Cooper and Schindler, 2003).

An ANOVA table was used to validate the results from the Independent T-test An ANOVA is utilized to uncover the main and interaction effects of independent variable on an interval variable. "The key test is the F-test of difference of group means, testing if the means of the groups formed by values of the independent variable are different enough not to have occurred by chance" (Retrieved from http://www2.chass.ncsu.edu /garson/pa765/statnote.htm, February, 12, 2005).

Throughout the study no direct patient information or personal information was used. General identifiers were used to identify whether procedure costs could be itemized to patients. There were no ethical considerations for this study.

## Results

The results for the weighting of the variables show the variable, reporting functionality, ranked highest among the 18 members of the QAC with a weighted score of 5.83. It was followed by the hospital's information management and logistical

strategic plan variables which ranked second and third with a ranking of 4.83 and 4.67, respectively. The lowest ranking variable was labor (skill set) with 2.72. See Appendix C for the complete weighting of the variables.

The overall totals show Pyxis was the system of choice based on the stated objective of the study. In fact, Pyxis was chosen over bar coding for each of the seven (7) variables that were addressed for the study. See Appendix D for complete selection results of the QAC.

The final table for phase one of the study, Table 3, summarizes that Pyxis (3.751) was chosen over bar coding (1.000E9) based on the variables used, the weighting of the variables, and the recommendation of the Quality Assurance Committee members selection of the system that best achieves the study's objective.

Table 3 – DEMAT Matrix

| **Weight** | **3.33** | **2.72** | **3.61** | **3.00** | **5.83** | **4.83** | **4.67** | **Total** |
|---|---|---|---|---|---|---|---|---|
| **Criteria** / **COA** | Labor (FTEs) | Labor (skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan | |
| Pyxis | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3.751 |
| Bar Coding | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.000E9 |

Further analysis of Tables 1, 2, and 3 was conducted per the guidance of the Commanding General, Brooke Army Medical Center, to determine specific results for three (3) sub-categories (physicians, OR staff, and administrative personnel). The results remain consistent with the overall findings for each table. Reporting functionality had the highest value and the hospital's information management and logistical strategic plan

variables were in the top five (5) for all three (3) groups. Additionally, the decision matrix tool, DECMAT, selected Pyxis over bar coding for all three (3) groups. The DECMAT results are listed in Table 4. A complete listing of the results for each group are in Appendices C, D, and E, respectively.

Table 4 DECMAT Results

| DECMAT Results | Physicians | OR Staff | Administrative Staff |
|---|---|---|---|
| Pyxis | 5.477 | 1.628 | 2.627 |
| Bar Coding | .0068011 | .002287 | .001417 |

The results for the second phase of the study are listed in Table 5. The table compares manual calculations for determining procedural costs using physician preference cards, prime vendor pricing sheets, and DMLSS. The manual calculations were compared to costs obtained using Pyxis for the same physician preference cards and CPT codes.

The total cost variance between the manual calculations and Pyxis is 2.6%. The variance among the CPT codes range from .3%, CPT code 22630 –Lumbar Fusion (single interspace, posterior interbody technique), to 10.1%, CPT code 33405, Prosthetic Heart Valve (Aortic).

Table 5. Manual Calculations vs. Pyxis

| **CPT Code** | **Title** | **Manual** | **Pyxis** | **Variance** |
|---|---|---|---|---|
| 22612 | Lumbar Fusion (posterior or posterolateral technique)(single interspace) | $1,048.59 | $1059.30 | $10.71<br>(1%) |
| 22558 | Anterior Lumbar Interbody Fusion | $1054.72 | $1090.18 | $35.46 |

| | | | | |
|---|---|---|---|---|
| | | | | (3.2%) |
| 22630 | Lumber Fusion (single interspace) (posterior interbody technique) | $4819.88 | $4836.85 | $16.97 (.3%) |
| 27130 | Total Hip Replacement | $7449.82 | $7654.14 | $204.32 (2.6%) |
| 27447 | Total Knee Replacement | $4619.42 | $4889.74 | $270.29 (5.5%) |
| 33405 | Prosthetic Heart Valve (Aortic) | $829.19 | $922.74 | $93.55 (10.1%) |
| 55873 | Cryoablation of the Prostate | $326.45 | $352.56 | $26.00 (7.3%) |
| 63075 | Anterior Cervical Discetomy, Single | $1,664.81 | $1589.12 | ($75.69) (4.5%) |
| **Total** | | **$21,812.88** | **$22,394.63** | **$581.75 (2.6%)** |

The information for the CPT codes, manual calculations, and Pyxis were entered into SPSS 12.0.1. The descriptive and inferential statistics are listed in Table 6 respectively. The mean for the eight (8) CPT codes for the manual calculations was $2,726.61, $2.799.33 for Pyxis, and $95.96 for the variance between the two systems. The standard deviation for manual was $2573.84, Pyxis was $2,646.08, and variance between the systems was $95.96.

Table 6. Descriptive Statistics

| Variable | Min | Max | Mean | SD |
|---|---|---|---|---|
| Manual | 326.45 | 7449.82 | 2726.61 | 2573.84 |
| Pyxis | 352.56 | 7654.14 | 2799.33 | 2646.08 |
| Variance from Manual and Pyxis Calculations | 10.71 | 270.29 | 91.62 | 95.96 |

All variables are measured in dollars ($)

Note: n=8 CPT codes, Data Source: Brooke Army Medical Center Operating Room Data

The inferential statistics listed in Table 6 display the findings for a T-test and ANOVA. Both tests were conducted to determine whether there was statistical significance between the values obtained for the manual and Pyxis calculations. The small F-test values of .015, Independent Samples Test, and .003, ANOVA, show there is no statistical significance between the manual calculations and Pyxis. Therefore, the costs calculated manually does not statistically vary from the costs calculated using Pyxis.

Table 7 – Inferential Statistics

**Independent Samples Test**

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Manual | Equal variances assumed | .015 | .903 | -.056 | 14 | .956 | -72.71875 | 1305.1056 | -2871.89 | 2726.454 |
| | Equal variances not assumed | | | -.056 | 13.989 | .956 | -72.71875 | 1305.1056 | -2872.09 | 2726.656 |

**ANOVA**

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 21152.066 | 1 | 21152.066 | .003 | .956 |
| Within Groups | 95384841 | 14 | 6813202.899 | | |
| Total | 95405993 | 15 | | | |

## Discussion

Tracking supply costs in the Operating Room is a daunting task even if organizations have systems that are multidimensional and integrated with the hospital's strategic long range plan. Systems and processes must be closely monitored to insure supply costs are accurate so organizations obtain the best product for the best price.

For this reason, a Quality Assurance Committee was used to help develop the variables to be utilized in the study. The members were chosen based on their positions and expertise with Pyxis and bar coding and their duties within the hospital. The committee consisted of physician staff (2), nursing staff (3), OR technician staff (8), and logistical/administrative staff (5). The 18 person committee included the Chief of Surgery, Chief of the Department of Health Care Operations, Chief of Perioperative Nursing, Chief of Central Material Services, Head Nurse for the Operating Room, Chief of Logistics, Chief of Material, Logistics, Chief of Property, Logistics, Department of Surgery Administrator, and Operating Technicians.

The committee members selected the variable, Reporting Functionality, as the most important variable of the seven variables that were used in the study. Reporting functionality is defined as the ability to generate standard and ad hoc reports to achieve reporting requirements by the by-laws of the organization and other regulatory private and public agencies such as the Joint Commission on Accreditation of Healthcare

Organizations, and other federal, state, and local governments. Since this study's research question pertains to reporting costs associated with various procedures, it is intuitive that this variable would rank near the top as being most important. Managers rely on standard and ad hoc reports to organize data and information into a logical and systematic format that can be understood by personnel throughout the organizations. These reports provide the framework for management to make decisions in a timely and accurate manner.

Technology plays in an important role in the delivery of healthcare. Advances in diagnostic services, movement towards an electronic medical record, electronic ordering of medical supplies, and advances in medical instrumentation and equipment help illustrate why Information Management and Logistic strategic plans were the next highest variables chosen. It is vital for all new automated systems that are purchased by health care organizations to be reviewed by the information management and logistical personnel. The main reason is to insure the systems are compatible with the strategic plan of the hospital and more importantly, the systems are compatible with current systems, possess expansion capacity, and identify maintenance requirements (Haag et al, 2004). Technology is constantly changing so the ability to expand is needed to meet current internal and external reporting requirements.

The ranking for Training/Ease of Use as the second lowest ranking was an interesting outcome. For the study, this variable was operationally defined as, "The simplicity of use (using competency check lists – the time it takes to train an individual to operate the system and understanding of the features of the system)." During the initial research for the study, several personnel from the operating room and Department of

Surgery addressed problems with using Pyxis in the operating room, which in part, was an initial reason for the development of this study. Their main concern was the time it took to train incoming personnel and the complexity of operating the system.

The next step in the first phase of the study compared Pyxis to bar coding using the variables and their definitions addressed previously and listed in Appendix B. Overall, 14 of the 18 committee members choose Pyxis over bar coding. To be consistent with the methodology of the study, Pyxis was selected over bar coding for each of the variables. The variables, Reporting Functionality, Information Strategic Plan, and Logistics Strategic Plan had the highest percentage of members choosing Pyxis over bar coding with 16 out 18 and 17 out of 18, respectively. The results show bar coding's highest total any variable was 6 out 18 for the variables, Labor (skill set) and Training/Ease of Use. These results show support for Pyxis based on the variables used.

The final step of the first phase of the study entered the weighted values of the variables into the decision matrix tool, the United States Army's DECMAT. The results show Pyxis with a total score of 3.751 is favored over Bar Coding with a total score of 1.000E9. These results were expected since Pyxis was chosen for all the variables.

The second phase of the study was designed to analyze how accurately the chosen system, Pyxis, could capture costs of various procedures. Physician preference cards were used for eight different current procedural terminology (CPT) codes and the costs of these procedures were manually calculated using prices from DMLSS and prime vendors. These costs were then analyzed with information obtained from Pyxis. The costs from Table 4 for each method were then entered into SPSS 12.0.1, a statistical software package, and analyzed using the descriptive and inferential statistics, Independent T-test

and ANOVA. The mean value for the variance between the manual calculations and Pyxis was $91.62 and the standard deviation was $95.96. These results illustrate that the average variance among the calculations for the eight (8) CPT codes was $91.62. The standard deviation value of $95.96 documents that approximately 68.24% of the values of the variances will range from -$4.34 to 187.58.

The results from Table 6 show an F-test value of .015 for the Independent T-test and .003 for the ANOVA table. The small values for both test show the groups do not differ significantly therefore, it is inferred that the independent variable(s) (Manual and Pyxis calculations) did not have an effect on the dependent variable (CPT codes). Thus, the small variance between the two methods of calculating costs is not statistically significant.

These results are consistent with the studies initial findings. The small variance can be accounted for by the use of similar charge sheets to calculate manual costs and Pyxis. The small variation may have contributed to Pyxis having more accurate pricing lists because the lists are updated through DMLSS on a real time basis.

A problem observed was the OR staff using the Pyxis machine incorrectly as the staff did not properly record items taken from the Pyxis machine. These infractions included taking items without pushing the "Take" button, pushing the "Take" button for an item and then not taking the item, not logging in under the correct patient, and taking to many items and not refilling the machine properly by pressing the "Return" button. These cases appear to be isolated incidents recognizing that the operational tempo in the OR is very high paced so errors may occur when documenting the supplies that were used for each procedure.

Another problem associated with Pyxis in the BAMC OR is the inability to include supplies obtained through contracts or credit card purchases. The OR has various contracts, such as Orthopedics for implant sets, for supplies that are not accounted for in DMLSS, and therefore must be inputted manually. This process of manually inputting data into DMLSS is very time consuming and expensive. Brooke Army Medical Center must employ numerous contractors to accomplish the requirement.

## Recommendations

Based on the results of the study, three recommendations are delineated. Overall, no matter what course of action is selected, the hospital leadership needs to place more command emphasize on the importance of accurately recording supplies utilized for all procedures conducted in the operating room. The Command needs to emphasis to the Operating Room staff that capturing accurate costs of supplies can lead to better information for making appropriate business decisions which can equate to increased efficiencies and revenue. Examples include prioritizing cases that generate more revenue for the hospital or referring cases to the network that can be performed cheaper outside the facility.

The first recommended course of action is to maintain the Pyxis machines in the operating room but conduct further research into implementing the Pyxis procedural module. Within the procedural module software is a "bill only" function that allows the OR logistical personnel to enter items, such as contract and credit card purchases, into Pyxis and produce itemized supply utilization reports by patient, provider, service, and procedure. The approximate time, per the regional Cardinal Health representative, to implement and train personnel to utilize the procedure module is 60 days. Within the

estimated 60 days, approximately one (1) hour per designated person is needed to train personnel. The training sessions would be scheduled before or after duty hours so the normal operations of the OR would not be effected. Since BAMC has an existing contract for Pyxis training, no additional cost is incurred by the hospital.

Additionally, the Logistics Department would coordinate with the OR staff to place four supply techs/contractors to manage the core areas during the duty day. The recommended wage grade for the person is GS-0622-06 with an annual cost per individual of $43,676 (step 5 pay level plus 25.4% benefits). An alternate to the GS worker is to hire a contractor. The benefit of hiring a contractor is BAMC does not pay the 25.4% benefits and the contract can be based on performance measures. The primary purpose of the logistical personnel is contract management, vendor relations and compliance, reprocessing initiatives, and the monitoring of cost control practices in the OR. This initiative places the responsibility of tracking supply usage on the logistical staff, relieves the OR nurses and techs from entering items into the Pyxis system, and will free time for the OR nurses and techs to focus solely on the patient. In short, it allows logistical personnel to do logistical work and OR personnel to do OR work.

A second course of action is course of action one plus conduct further research into augmenting the Pyxis machines with bar coding technology. The bar coding technology should have, at a minimum, the capability to capture supplies obtained from contractors, credit card purchases, and other supplies not listed in the DMLSS system. Additionally, the bar coding technology should have the ability to use a portable scanner and touch screen technology to itemize supplies for each patient procedure. Initial research into purchasing this technology reveals that Cardinal Health has a product called

ScanAssist 250/500. ScanAssist is a portable and wireless bar coding system that is integrated with existing Pyxis supply cabinets, such as those that are used in the operating room. Although an exact cost has not been identified, the regional sales representative from Cardinal Health provided a quote of approximately $12,000.

A third course of action is to remove all the Pyxis machines from the OR and replace them with bar coding technology. This course of action is not recommended by the research for several reasons. First, the data from the Quality Assurance Committee recommended Pyxis over bar coding. Out of a possible 126 (18 members multiplied by 7 variables) opportunities, Pyxis was selected 102 times. Showing overwhelming support that Pyxis is preferred over bar coding. Second, an initial proposal to implement bar coding technology for all 12 OR rooms was $225,000, with a completion timeline of six months. This proposal includes the time, resources, and money associated with the removal of the Pyxis machines. It also includes the labor, equipment, training, and implementation of bar coding technology. Finally, bar coding technology does not allow organizations the ability to monitor par levels which impacts automated re-order requests for supplies and leads to time delays as more people are needed to input the requests.

If Brooke Army Medical Center chooses to implement course of action one and two, they will be provided with a more accurate cost accounting system to track supplies utilized in the OR. This will allow the BAMC staff the ability to conduct a comparative analysis between the cost of procedures performed at BAMC and the TRICARE Management Activity (TMA) CHAMPUS Maximum Allowable Charge (CMAC) rates. This analysis will provide data to assist BAMC in requesting higher reimbursement rates from TMA for procedures that exceed the CMAC rates. With more accurate supply cost

information, BAMC can justify its request for higher reimbursement rates based on higher supply costs associated with this section of the country.

The ability to determine the cost of surgical procedures also allows the BAMC OR staff to prioritize cases that generate more revenue for the hospital. A comparative analysis can also be conducted with local area network facilities to determine whether cost savings can be achieved by performing lower revenue generating procedures outside BAMC.

One last value of implementing the recommended course of actions is it allows BAMC to analyze the cost of procedure by provider and service. This information is useful for utilization review and can be used to develop 'best practices" among providers and services for similar procedures.

## Study Limitations

These limitations were highlighted by the researcher according to what he felt had the greatest influence on the study. However, other limitations may be more important. First, due to academic requirements, the timeframe of the study was condensed. A longer timeframe for the study may produce more desirable results as future researchers can visit and gather data from similar facilities.

Second, future research might consider different variables or weighting the responses of the committee members. Other variables could result in different outcomes for the study; however, the study relied on the expertise of the QAC to increase the validity and reliability of the variables and their definitions. Additionally, each member of the QAC had equal weight on the variable definitions, weighting of the variables, and

choosing which system was preferred, Pyxis vs. bar coding. The weighting of the responses can be based on experience or duty position.

Third, this study only compared Pyxis to bar coding and did not consider other systems. Future research should assess the efficiency of other systems in relation to Pyxis. Continued research is needed to ensure that organizations analyze their business strategies, align business processes with their strategies, and purchase technology accordingly, whether it is one system or a hybrid of systems.

## Conclusions

The ability to determine per case costs and then track costs is a critical input for the development of budgets and for hospitals competing with other health care facilities, especially those organizations that are bidding on any type of pricing contracting. The inability to clearly identify costs with a high degree of certainty severely handicaps an organization who must go out into the market to purchase supplementary care. The management and information systems support are critical if costs are to be accurately identified. Once this information can be obtained consistently and with a high degree of accuracy, an analysis of total cost per case can be conducted, allowing for efficient and effective contracting and outsourcing of services.

The development of the Pyxis system in a manner consistent with recommended course of action number two can provide the necessary tool for making accurate cost data collection a reality.

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Appendix A – Operational Definitions of Variables

1. Labor (required FTEs) – the number of full time equivalents (FTE) required to efficiently staff the core area within the operating room.

2. Labor (skill set) – the required staff mix to staff the core area of the operating room (i.e. logistical supply techs, OR supply techs, or circulating nurses).

3. Start up and Maintenance costs – the cost associated with installing and maintaining each system and the average down time of the system.

4. Training/Ease of use – the simplicity of use (time it takes to train an individual to operate the system, understanding of the features of the system).

5. Reporting Functionality- the ability to generate standard and ad hoc reports to achieve reporting requirements of the organization.

6. IM strategic plan– the system meets the information management plan of the hospital.

7. Logistics strategic plan- the system meets the logistical management plan of the hospital.

## Appendix B – Questionnaire to Weight Variables

Name - ________________ Date- _______
Duty Title - ______________

Operational Definition of Variables

- Labor (required FTEs) – the number of full time equivalents (FTE) required to efficiently staff the core area within the operating room.
- Labor (skill set) – the required staff mix to staff the core area of the operating room (i.e. logistical supply techs, OR supply techs, or circulating nurses).
- Start up and Maintenance costs – the cost associated with installing and maintaining each system and the average down time of the system.
- Training/Ease of use – the simplicity of use (time it takes to train an individual to operate the system, understanding of the features of the system).
- Reporting Functionality- the ability to generate standard and ad hoc reports to achieve reporting requirements of the organization.
- IM strategic plan– the system meets the information management plan of the hospital.
- Logistics strategic plan- the system meets the logistical management plan of the hospital.

**Please rank order the above variables in order of importance one (1) = lowest to seven (7) highest.**

____ Labor (required FTEs) ____ Labor (skill set)
____ Maintenance ____ Training/Ease of use
____ Reporting Functionality ____ IM strategic plan
____ Logistics strategic plan

**Please (X) the blank for each variable as to which system best accomplishes the task of identifying costs per procedure and assigning costs to patients:**

| Pyxis | Variable | Bar Coding |
|---|---|---|
| ____ | Labor (required FTEs) | ____ |
| ____ | Labor (skill set) | ____ |
| ____ | Maintenance | ____ |
| ____ | Training/Ease of use | ____ |
| ____ | IM strategic plan | ____ |

Appendix C – Table 1 - Weighting of Variables

| Name | Section | Labor (Req FTEs) | Labor (Skill Set) | Manten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan |
|---|---|---|---|---|---|---|---|---|
| Chief, Surgery | Surgery | 3 | 5 | 4 | 7 | 6 | 1 | 2 |
| Chief, DHCO | DHCO | 1 | 2 | 4 | 3 | 5 | 7 | 6 |
| Chief, PONS | OR | 6 | 3 | 5 | 4 | 7 | 1 | 2 |
| Head Nurse, OR | OR | 4 | 5 | 6 | 3 | 7 | 2 | 1 |
| Chief, Logistics | Log | 3 | 2 | 4 | 1 | 5 | 7 | 6 |
| Chief, CMS | CMS | 4 | 3 | 2 | 1 | 5 | 7 | 6 |
| Chief, Property Branch | Log | 7 | 3 | 1 | 2 | 6 | 5 | 4 |
| Administrator | Surgery | 6 | 2 | 1 | 5 | 7 | 3 | 4 |
| Chief, Material Branch | Log | 1 | 2 | 5 | 3 | 4 | 7 | 6 |
| Deputy Chief, Material Branch | Log | 1 | 2 | 6 | 7 | 5 | 4 | 3 |
| OR Tech #1 | OR | 3 | 4 | 2 | 1 | 7 | 5 | 6 |
| OR Supply NCO | OR | 5 | 2 | 3 | 1 | 7 | 4 | 6 |
| OR Tech #2 | OR | 3 | 4 | 2 | 1 | 7 | 5 | 6 |
| OR Tech #3 | OR | 3 | 2 | 4 | 1 | 5 | 6 | 7 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| OR Tech #4 | OR | 2 | 1 | 4 | 3 | 7 | 6 | 5 |
| OR Tech #5 | OR | 2 | 3 | 4 | 1 | 5 | 7 | 6 |
| OR Log Tech #1 | OR | 3 | 2 | 1 | 4 | 5 | 6 | 7 |
| OR Log Tech #2 | OR | 3 | 2 | 7 | 6 | 5 | 4 | 1 |
| **Totals** | | 60 | 49 | 65 | 54 | 105 | 87 | 84 |
| ***Weighted Values (Total Rankings/18)** | | **3.33** | **2.72** | **3.61** | **3.00** | **5.83** | **4.83** | **4.67** |
| *Based on 18 Rankings | | **5** | **7** | **4** | **6** | **1** | **2** | **3** |

Appendix D – Table 2 – Pyxis vs. Bar Coding

| Name | Section | Labor (Req FTEs) | Labor (Skill Set) | Manten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan |
|---|---|---|---|---|---|---|---|---|
| Chief, Surgery | Surgery | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding |
| Chief, DHCO | DHCO | Pyxis | Bar Coding | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis |
| Chief, PONS | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Head Nurse, OR | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Chief, Logistics | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Chief, CMS | CMS | Bar Coding | Bar Coding | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis |
| Chief, Property Branch | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Administrator | Surgery | Bar Coding | Bar Coding | Pyxis | Bar Coding | Bar Coding | Pyxis | Pyxis |
| Chief, Material Branch | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Deputy Chief, Material Branch | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Tech #1 | OR | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Pyxis | Pyxis | Pyxis |
| OR Supply NCO | OR | Pyxis | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Tech #2 | OR | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Pyxis | Pyxis | Pyxis |
| OR Tech #3 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| OR Tech #4 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Tech #5 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Log Tech #1 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Log Tech #2 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| **Choice per Variable** | | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** |

Appendix E – Physician Weighting of Variables, Pyxis vs. Bar Coding, and DECMAT

| Name | Section | Labor (Req FTEs) | Labor (Skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan |
|---|---|---|---|---|---|---|---|---|
| Chief, Surgery | Surgery | 3 | 5 | 4 | 7 | 6 | 1 | 2 |
| Chief, DHCO | DHCO | 1 | 2 | 4 | 3 | 5 | 7 | 6 |
| Chief, PONS | OR | 6 | 3 | 5 | 4 | 7 | 1 | 2 |
| Head Nurse, OR | OR | 4 | 5 | 6 | 3 | 7 | 2 | 1 |
| Chief, CMS | CMS | 4 | 3 | 2 | 1 | 5 | 7 | 6 |
| **Totals** | | 18 | 18 | 21 | 18 | 30 | 18 | 17 |
| ***Weighted Values (Total Rankings/5)** | | **3.60** | **3.60** | **4.20** | **3.60** | **6.00** | **3.60** | **3.40** |
| *Based on 5 Rankings | | **3** | **3** | **2** | **3** | **1** | **3** | **7** |

| **Name** | **Section** | **Labor (Req FTEs)** | **Labor (Skill Set)** | **Mainten-ance** | **Training/ Ease of Use** | **Reporting Function** | **IM Strat Plan** | **Logistics Strat Plan** |
|---|---|---|---|---|---|---|---|---|
| Chief, Surgery | Surgery | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding |
| Chief, DHCO | DHCO | Pyxis | Bar Coding | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis |
| Chief, PONS | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Head Nurse, OR | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Chief, CMS | CMS | Bar Coding | Bar Coding | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis |
| **Choice per Variable** | | **Pyxis** | **Bar Coding** | **Pyxis** | **Bar Coding** | **Pyxis** | **Pyxis** | **Pyxis** |

| Weight | 3.60 | 3.60 | 4.20 | 3.60 | 6.00 | 3.60 | 3.60 | Total |
|---|---|---|---|---|---|---|---|---|
| Criteria / COA | Labor (FTEs) | Labor (skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan | |
| Pyxis | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 5.477 |
| Bar Coding | 1 | 2 | 1 | 2 | 1 | 1 | 1 | .0068011 |

# Appendix F – OR Staff Weighting of Variables, Pyxis vs. Bar Coding, and DECMAT

| Name | Section | Labor (Req FTEs) | Labor (Skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan |
|---|---|---|---|---|---|---|---|---|
| Chief, Surgery | Surgery | 3 | 5 | 4 | 7 | 6 | 1 | 2 |
| Chief, DHCO | DHCO | 1 | 2 | 4 | 3 | 5 | 7 | 6 |
| Chief, PONS | OR | 6 | 3 | 5 | 4 | 7 | 1 | 2 |
| Head Nurse, OR | OR | 4 | 5 | 6 | 3 | 7 | 2 | 1 |
| Chief, CMS | CMS | 4 | 3 | 2 | 1 | 5 | 7 | 6 |
| OR Tech #1 | OR | 3 | 4 | 2 | 1 | 7 | 5 | 6 |
| OR Supply NCO | OR | 5 | 2 | 3 | 1 | 7 | 4 | 6 |
| OR Tech #2 | OR | 3 | 4 | 2 | 1 | 7 | 5 | 6 |
| OR Tech #3 | OR | 3 | 2 | 4 | 1 | 5 | 6 | 7 |
| OR Tech #4 | OR | 2 | 1 | 4 | 3 | 7 | 6 | 5 |
| OR Tech #5 | OR | 2 | 3 | 4 | 1 | 5 | 7 | 6 |
| **Totals** | | 36 | 34 | 40 | 26 | 68 | 51 | 53 |
| ***Weighted Values (Total Rankings/11)** | | **3.27** | **3.09** | **3.64** | **2.36** | **6.18** | **4.64** | **4.82** |
| *Based on 11 Rankings | | **5** | **6** | **4** | **7** | **1** | **3** | **2** |

| Name | Section | Labor (Req FTEs) | Labor (Skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan |
|---|---|---|---|---|---|---|---|---|
| Chief, Surgery | Surgery | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Bar Coding |
| Chief, DHCO | DHCO | Pyxis | Bar Coding | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis |
| Chief, PONS | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Head Nurse, OR | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Chief, CMS | CMS | Bar Coding | Bar Coding | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis |
| OR Tech #1 | OR | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Pyxis | Pyxis | Pyxis |
| OR Supply NCO | OR | Pyxis | Pyxis | Bar Coding | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Tech #2 | OR | Bar Coding | Bar Coding | Bar Coding | Bar Coding | Pyxis | Pyxis | Pyxis |
| OR Tech #3 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Tech #4 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Tech #5 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| **Choice per Variable** | | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** |

| **Weight** | **3.27** | **3.09** | **3.64** | **2.36** | **6.18** | **4.64** | **4.82** | **Total** |
|---|---|---|---|---|---|---|---|---|
| **Criteria** / **COA** | Labor (FTEs) | Labor (skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan | |
| Pyxis | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1.628 |
| Bar Coding | 1 | 1 | 1 | 1 | 1 | 1 | 1 | .002287 |

# Appendix G – Administrative Weighting of Variables, Pyxis vs. Bar Coding, and DECMAT

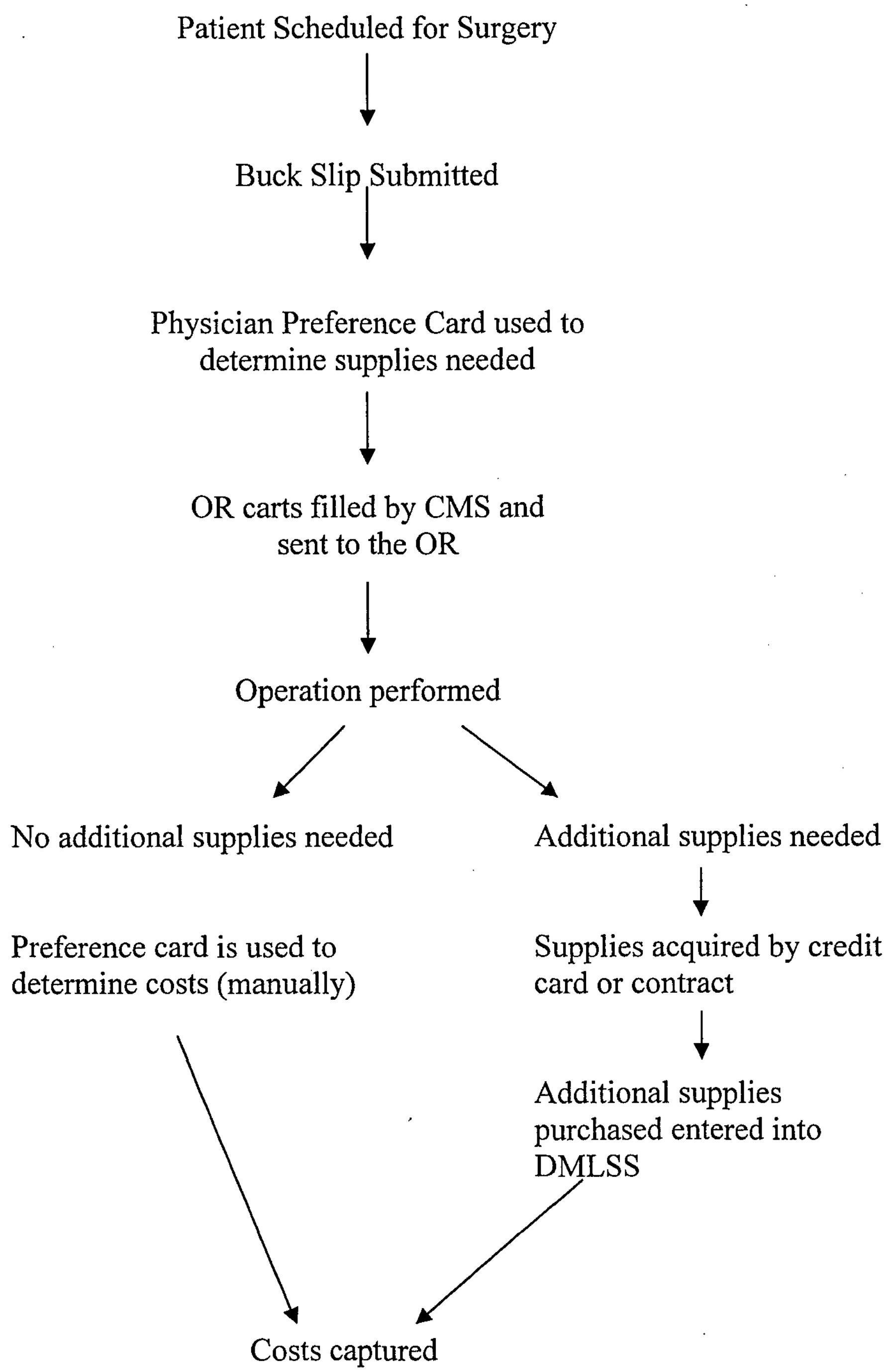
| Name | Section | Labor (Req FTEs) | Labor (Skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan |
|---|---|---|---|---|---|---|---|---|
| Chief, Logistics | Log | 3 | 2 | 4 | 1 | 5 | 7 | 6 |
| Chief, Property Branch | Log | 7 | 3 | 1 | 2 | 6 | 5 | 4 |
| Administrator | Surgery | 6 | 2 | 1 | 5 | 7 | 3 | 4 |
| Chief, Material Branch | Log | 1 | 2 | 5 | 3 | 4 | 7 | 6 |
| Deputy Chief, Material Branch | Log | 1 | 2 | 6 | 7 | 5 | 4 | 3 |
| OR Log Tech #1 | OR | 3 | 2 | 1 | 4 | 5 | 6 | 7 |
| OR Log Tech #2 | OR | 3 | 2 | 7 | 6 | 5 | 4 | 1 |
| **Totals** | | 24 | 15 | 25 | 28 | 37 | 36 | 31 |
| ***Weighted Values (Total Rankings/7)** | | **3.43** | **2.14** | **3.57** | **4.00** | **5.29** | **5.14** | **4.43** |
| *Based on 7 Rankings | | **6** | **7** | **5** | **4** | **1** | **2** | **3** |

| Name | Section | Labor (Req FTEs) | Labor (Skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan |
|---|---|---|---|---|---|---|---|---|
| Chief, Logistics | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Chief, Property Branch | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Administrator | Surgery | Bar Coding | Bar Coding | Pyxis | Bar Coding | Bar Coding | Pyxis | Pyxis |
| Chief, Material Branch | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| Deputy Chief, Material Branch | Log | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Log Tech #1 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| OR Log Tech #2 | OR | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis | Pyxis |
| **Choice per Variable** | | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** | **Pyxis** |

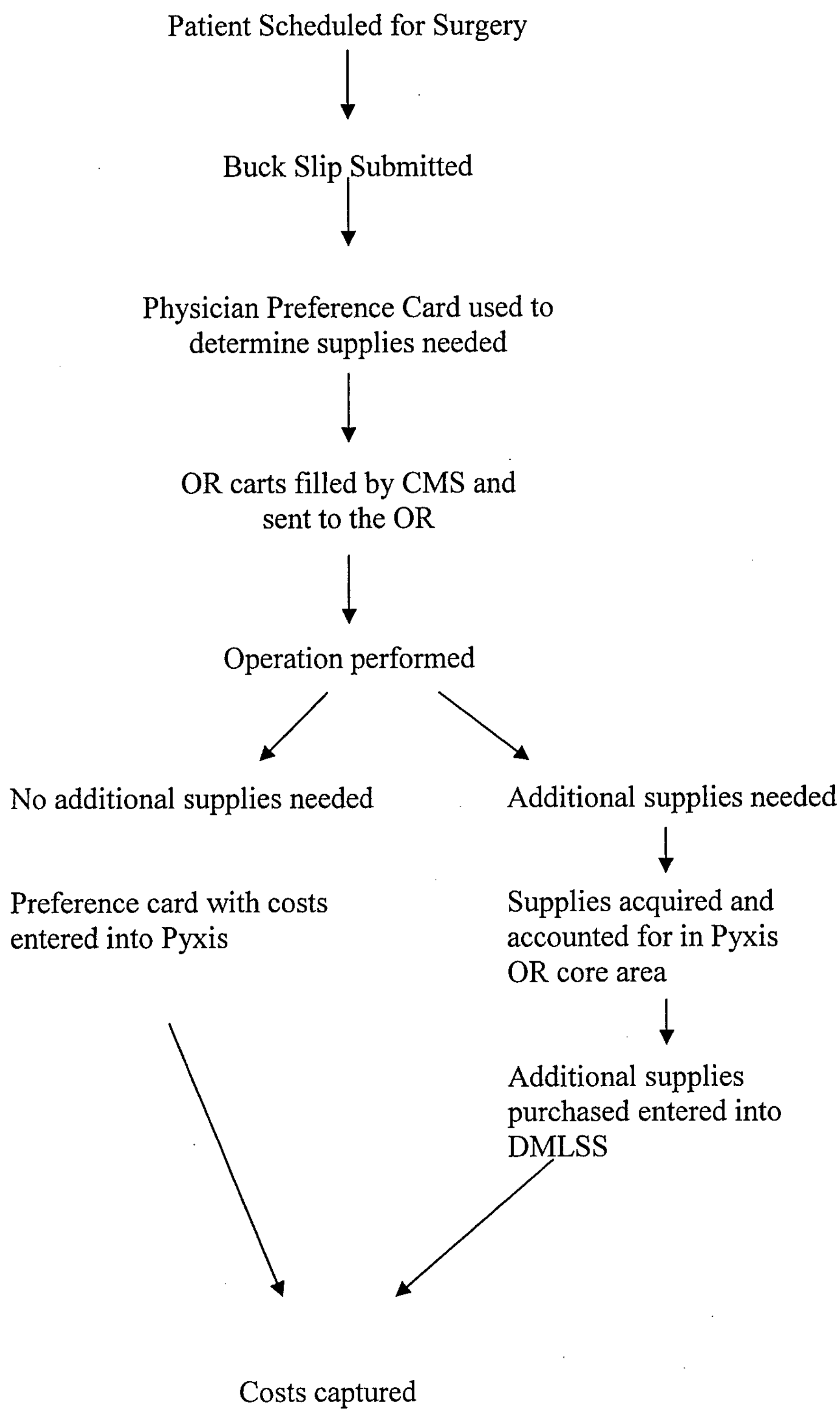
| **Weight** | **3.43** | **2.14** | **3.57** | **4.00** | **5.29** | **5.14** | **4.43** | **Total** |
|---|---|---|---|---|---|---|---|---|
| **Criteria** / **COA** | Labor (FTEs) | Labor (skill Set) | Mainten-ance | Training/ Ease of Use | Reporting Function | IM Strat Plan | Logistics Strat Plan | |
| Pyxis | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2.627 |
| Bar Coding | 1 | 1 | 1 | 1 | 1 | 1 | 1 | .001417 |

Appendix H – Flowchart of Operating Supply Usage

**Manual Process**



Pyxis


Patient Scheduled for Surgery
Buck Slip Submitted
Physician Preference Card used to determine supplies needed
OR carts filled by CMS and sent to the OR
Operation performed
No additional supplies needed
Additional supplies needed
Preference card with costs entered into Pyxis
Supplies acquired and accounted for in Pyxis OR core area
Additional supplies purchased entered into DMLSS
Costs captured